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Luminescence enhancement in indirect band-gap semiconductors with quantum confinement structures

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In order to obtain efficient light emission from indirect band-gap semiconductors, we have systematically investigated the correlation between electronic states and optical properties in three kinds of novel quantum confinement structures.

The first one is a neighboring confinement structure (NCS) in which a pair of thin layers of spatially indirect band-gap semiconductors is sandwiched by a wider band-gap barrier layers. The usefulness of this structures, that is, increase of luminescence, especially no-phonon emission, and thermal stability of luminescence was demonstrated for GaP/AIP NCS structures where the GaP/AIP pair was sandwiched by AlGaP barrier layers. The luminescence was proven to be further enhanced by growing the structure on InGaP pseudo-substrates. This enhancement can be attributed to Γ -X band mixing and the increase of wavefunction overlap caused by the strain. These NCS structures were demonstrated to be applicable to Si/Ge heterostructures and systematic energy shift and significant luminescence enhancement were clearly observed.

The second structure is a quantum well which contains an ultrathin AIP layer at the center of type-I indirect GaAsP/GaP quantum wells (QWs) so that electrons are effectively localized into the well region. Insertion of 1-ML of AIP into the center of GaAsP QWs was found to drastically increase luminescence intensity. The study on As composition and AIP thickness dependencies as well as numerical calculation revealed that exciton localization is preferable for enhancement of luminescence when the Xz band rather than Xxy bands constructs the quantum well.

An ultimate structure for exciton localization in indirect band-gap materials is the quantum dot structure. Formation of Ge dots on Si layers was investigated and it was found that well-controlled dot array can be realized by employing electron-beam lithography and selective epitaxial growth of gas source MBE of Ge on Si layers with SiO₂ masks. The numbers and size of Ge dots are dependent on growth conditions, especially the size of SiO₂ windows, reflecting migration length of Ge atoms. Significant luminescence is observed from the dot array and the attempt to reduce the dot size is now under progress to enhance the quantum confinement effects in the dots.